BIOASSESSMENT REPORT

RAPID BIOASSESSMENT OF THE

PIPE CREEK WATERSHED

USING BENTHIC MACROINVERTEBRATES

October 2002 and May 2003

For the
Soil and Water Conservation District of Howard County

Study Conducted By:

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TABLE OF CONTENTS

APPENDICES

    Photographs of Study Sites

    Macroinvertebrate Identification Literature

    Bioassessment Summary

EXECUTIVE SUMMARY

A rapid bioassessment technique was used to determine the ecological health of Pipe Creek and three of its tributaries in central Indiana prior to implementation of various land treatments in the watershed by the local SWCDs. Water chemistry and the benthic communities of ten sites, including a reference site, were sampled during October 2002 and May 2003 to provide information on "before treatment" conditions in the watershed.

Water chemistry results showed that turbidity, nutrient, and bacteria concentrations were highly variable. During October, water chemistry at all sites indicated relatively good conditions in the watershed. However, the May samples gave a different picture. Turbidity, nitrogen, phosphorus, chlorophyl and E.coli were roughly ten times higher than in May and were indicative of degraded conditions.

The biological sampling showed that all of the sites in the Pipe Creek watershed had biotic index values less than the reference site during October. These sites showed "slight" to "severe" impacts. The average watershed index of biotic integrity was 51% of the total from a nearby "reference" stream. Differences from the reference stream were due to degraded habitat quality at most sites. Water quality impacts from excessive nutrient and sediment inputs and from periodically low dissolved oxygen were also present. This was especially true in the upper reaches of Honey Creek and in Pipe Creek as it entered the study area.

During the May sampling period, biotic integrity had improved somewhat. The average watershed index of biotic integrity had increased to 62% of the total from the reference stream. In fact, biotic index values were significantly greater than the habitat values at several sites (Little Pipe Creek and lower Honey Creek). This effect is frequently associated with excessive nutrient inputs.

Recommendations to improve the condition of streams in the watershed include bank stabilization using vegetative techniques, limiting access to the stream by livestock, and restoring trees along streambanks. Implementation of best management practices (BMPs) for sediment and nutrient control should be encouraged throughout the watershed, especially in the upper Honey Creek and Little Pipe Creek areas. It would be a good idea to do a similar biological monitoring program within five years to gauge the success of BMP implementation.

INTRODUCTION

This study was conducted to measure the "biological integrity" of upper Pipe Creek and three of its tributaries in central Indiana. Pipe Creek is a tributary of the Wabash River and is listed by the Indiana Department of Environmental Management (IDEM) as having seriously degraded water quality due to nonpoint sources of pollution such as excessive sediment and nutrient inputs from stormwater runoff [1].

To deal with this problem, the Howard County Soil and Water Conservation District sought and received a grant from the Indiana Department of Natural Resources to develop a soil conservation plan to help reduce nonpoint source problems in the stream. Prior to implementing the plan, the SWCD office decided to conduct a benthic study of the stream to document "before treatment" conditions. The results would be incorporated into a watershed diagnostic study by the SWCD staff.

Local Setting

Pipe Creek is located in the "Central Corn Belt Plain" ecoregion of the Central U.S. [2]. The land in the watershed was molded by glacier activity and is relatively flat. The original forests were dominated by beech, maple, oak, and hickory trees but row crop agriculture and livestock grazing are the most common land uses today. In fact, about 95% of the watershed is devoted to agricultural uses. Only about 5% remains forested [19]. Several small urban areas (Converse, Sims, Sycamore, and Amboy) are also present in the watershed.
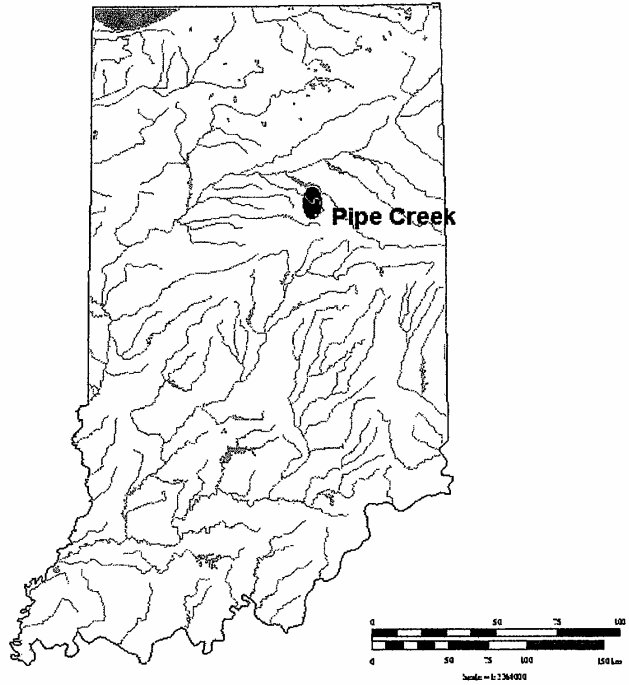
Figure 1. **Pipe Creek Watershed**

Ten sites were sampled during this study. Watershed areas [18] and GPS coordinates of each site are shown below:

		Area	Latitude	Longitude
Site 1	Pipe Creek at CR 1100 S	72 mi^2	40.36.541	85.52.254
Site 2	Pipe Creek at CR 800 E	97 mi^2	40.37.687	85.55.266
Site 3	Little Pipe Creek at CR 200 N	5 mi^2	40.30.444	85.53.006
Site 4	Little Pipe Creek @ 600 N	12 mi^2	40.33.930	85.52.129
Site 5	Little Pipe Creek @ CR 1100 S	21 mi^2	40.36.541	85.52.943
Site 6	Sugar Creek at Hwy 18	13 mi^2	40.34.742	85.56.079
Site 7	Honey Creek at Hwy 18	9 mi^2	40.34.742	85.57.078
Site 8	Honey Creek at CR 1050 S	27 mi^2	40.36.956	85.55.304
Site 9	Potter Ditch at CR 1100 S	3 mi^2	40.36.863	85.52.254
Site 10	Little Deer Creek (ref. site)	34 mi^2	40.33.530	86.24.100

Figure 2.   Study Sites on Pipe Creek
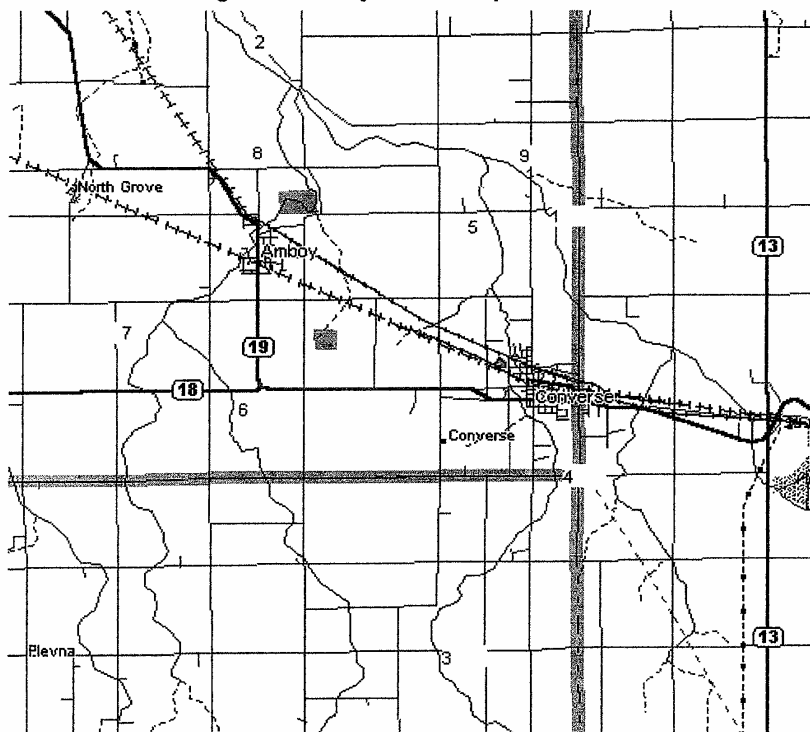
METHODS

Because they are considered to be more sensitive to local conditions and respond relatively rapidly to environmental change [3], benthic (bottom-dwelling) organisms were used to document the biological condition of each stream. The U.S. Environmental Protection Agency (EPA) has recently developed a "rapid bioassessment" protocol [4] which has been shown to produce highly reproducible results that accurately reflect changes in water quality. We used EPA's Protocol III to conduct this study. Protocol III requires a standardized collection technique, a standardized subsampling technique, and identification of at least 100 animals from each site to the genus or species level from both "study sites" and a "reference site." CPOM (Coarse Particulate Organic Matter) samples were collected and analyzed to determine the percentage of shredder organisms.

Reference Site

The aquatic community of a reference site is compared to that of each study site to determine how much impact has occurred. The reference site should be in the same "ecoregion" as the study sites and be approximately the same size. It should be as pristine as possible, representing the best conditions possible for that area.

A recent study [5] found that Little Deer Creek had one of the best fish communities and habitat values in the area. Little Deer Creek has a drainage area which is similar to the study sites, is nearby, and is in the same ecoregion. Therefore, Little Deer Creek (Site 10) was used as the basis of comparison for all other sites in the study.

Habitat Analysis

Habitat analysis was conducted according to Ohio EPA methods [21]. In this technique, various characteristics of a stream and its watershed are assigned numeric values. All assigned values are added together to obtain a "Qualitative Habitat Evaluation Index." The highest value possible with this habitat assessment technique is 100.

Water Chemistry

Water chemistry measurements were made at each study site on the same day that macroinvertebrate samples were collected. Dissolved oxygen was measured by the membrane electrode method. The pH and temperature measurements were made with an Oakton pH/temp. probe. Conductivity was measured with a Hanna Instruments meter. All instruments were calibrated in the field prior to measurements.

Grab samples for nutrient and E.coli were collected and returned to the laboratory for analysis. Ammonia was measured by the selective ion probe method. Nitrate was measured by cadmium reduction and spectrophotometry at 530 nm. Phosphorus was measured by the ascorbic acid method and spectrophotometry at 660 nm. Chlorophyl and turbidity were measured by fluorometry. E.coli were measured by membrane filtration, using m-coliblue as the media.

Macroinvertebrate Sample Collection

Samples in this study were collected by kicknet from riffle habitat where current speed was 20-30 cm/sec. Riffles were used because they typically support the most diverse benthic community in streams. The kicknet was placed immediately downstream from the riffle while the sampler used a hand to dislodge all attached benthic organisms from rocks upstream from the net. The organisms were swept by the current into the kicknet and subsequently transferred to a white pan. Each sample was examined in the field to assure that at least 100 organisms were collected at each site. In addition, each site was sampled for organisms in CPOM (coarse particulate organic matter, usually consisting of leaf packs from fast-current areas). All samples were preserved in the field with 70% ethanol.

Laboratory Analysis

In the laboratory, a 100 organism subsample was prepared from each site by evenly distributing the whole sample in a white, gridded pan. Grids were randomly selected and all organisms within grids were removed until 100 organisms had been selected from the entire sample.

Each animal was identified to the lowest practical taxon (usually genus or species). As each new taxon was identified. a representative specimen was preserved as a "voucher." All voucher specimens have been deposited in the Purdue University Department of Entomology collection.

RESULTS

Aquatic Habitat Analysis

When the Ohio EPA habitat scoring technique was used, the following aquatic habitat values were obtained for each site in the study:

	QHEI	Area (sq mi)	Substrate	Cover	Channel	Riparian	Pool/ Riffle	Gradient	QHEI % of
Maximum	100	15	15	15	15	15	15	10	Reference
Pipe Creek CR 1100 S	73	11 (72)	10	10	13	11	10	8	100
Pipe Creek CR 800 E	71	11 (97)	10	9	13	10	12	6	99
Little Pipe Cr. CR 200 N	36	6 (5)	6	3	6	7	2	6	50
Little Pipe Cr. County Line	50	8 (12)	10	3	7	5	9	8	69
Little Pipe Cr. CR 1100 S	46	9 (21)	6	4	6	7	6	8	64
Sugar Creek Hwy 18	48	8 (13)	8	5	6	7	8	6	67
Honey Creek Hwy 18	35	7 (9)	2	6	6	8	0	6	49
Honey Creek CR 1050 S	70	9 (27)	12	8	11	9	11	10	97
Potter Ditch CR 1050 E	56	5 (3)	10	6	9	7	9	10	78
Little Deer Cr. Hwy 29	72	10 (34)	12	9	12	9	14	6	100

7

The maximum value obtainable by this scoring technique is 100, with higher values indicating better habitat. Sites with lower habitat values normally have lower biotic index values as well.

The scores indicate that the lowest habitat value in this study was at Sites 3 and 7 (most upstream sites on Little Pipe Creek and Honey Creek). Habitat at these sites was hampered by a paucity of stable bottom substrate and instream cover, by the lack of any riparian buffer zone, by intermittent flow, and by bank erosion. There was no flow at these sites prior to October 2002, and aquatic habitat was reduced to shallow, isolated pools for much of the summer.

Water Quality Measurements
October 8, 2002

Site	D.O. mg/l	pH SU	Cond uS	Temp C	ChlA ug/l	Turb NTU	NO3 mg/l	NH3 mg/l	PO4 mg/l Total	PO4 mg/l Ortho	E.coli /100 ml
Pipe Creek CR 1100 S	10.6	7.8	600	11.1	17.6	0.6	0.52	0.1	0.26	0.10	112
Pipe Creek CR 800 E	10.8	8.1	500	12.6	15.0	1.1	0.52	0.1	0.28	0.11	38
Little Pipe Cr. CR 200 N	11.5	8.3	500	13.7	85.4	7.8	0.41	0.2	0.15	0.13	4
Little Pipe Cr. County Line	11.1	8.2	500	12.6	65.0	6.0	0.52	0.2	0.10	0.06	87
Little Pipe Cr. CR 1100 S	11.4	8.3	600	13.6	56.0	4.6	0.38	0.1	0.18	0.10	19
Sugar Creek Hwy 18	10.8	7.9	500	14.8	14.2	1.1	0.44	0.1	0.26	0.17	122
Honey Creek Hwy 18	12.1	9.0	500	16.8	141	56	0.60	0.1	0.11	0.06	138
Honey Creek CR 1050 S	11.0	8.1	500	12.3	24.4	2.8	0.65	0.1	0.16	0.16	42
Potter Ditch CR 1050 E	10.3	7.7	500	10.7	17.5	2.1	0.44	0.1	0.12	0.10	187
Little Deer Cr. Hwy 29	10.8	7.8	500	11.0	18.1	5.7	0.95	0.2	0.10	0.05	120

D.O. = Dissolved Oxygen
Cond. = Conductivity
ChlA = Chlorophyl a
Turb. = Turbidity
NH3 = Ammonia (as Nitrogen)
NO3 = Nitrite + nitrate (as Nitrogen)
PO4 = Phosphate (as Phosphorus)

Water Quality Measurements
May 5, 2003

Site	D.O. mg/l	pH SU	Cond uS	Temp C	ChlA ug/l	Turb NTU	NO3 mg/l	NH3 mg/l	PO4 mg/l Total	PO4 mg/l Ortho	E.coli /100 ml
Pipe Creek CR 1100 S	9.3	7.6	390	14.0	257	344	27.5	1.1	1.10	0.76	780
Pipe Creek CR 800 E	9.7	7.7	420	13.0	223	384	22.5	0.9	0.76	0.58	1120
Little Pipe Cr. CR 200 N	9.8	7.5	420	14.0	196	210	32.5	1.0	0.44	0.35	660
Little Pipe Cr. County Line	9.7	7.5	390	12.5	231	336	25.0	1.4	0.90	0.70	1320
Little Pipe Cr. CR 1100 S	9.3	7.6	370	13.0	277	465	17.5	0.9	0.80	0.68	1060
Sugar Creek Hwy 18	9.4	7.6	400	13.5	217	296	30.0	0.8	0.35	0.26	980
Honey Creek Hwy 18	8.6	7.8	400	13.5	127	82	27.5	0.5	0.36	0.21	900
Honey Creek CR 1050 S	9.1	7.5	420	13.0	231	200	23.8	0.8	0.48	0.36	1140
Potter Ditch CR 1050 E	8.7	7.4	410	15.0	143	152	40.0	1.0	0.90	0.72	780
Little Deer Cr. Hwy 29	9.4	7.2	500	15.0	164	67	26.3	0.7	0.44	0.30	2180

D.O. = Dissolved Oxygen
Cond. = Conductivity
ChlA = Chlorophyl a
Turb. = Turbidity
NH3 = Ammonia (as Nitrogen)
NO3 = Nitrite + nitrate (as Nitrogen)
PO4 = Phosphate (as Phosphorus)

10

Mussel Observations

Mussels were observed at both sites 1 and 2 in Pipe Creek. Species present included:

Sites

Lampsilis siliquoidea	10 (live)
Anodontoides ferussacianus	10 (1 valve)
Fusconaia flava	10 (1 valve)
Toxolasma parvus	10 (1 valve)
Amblema plicata	1,2, 10 (live)
Pyganodon grandis	8 (2 valves)

11

Table 1.
Rapid Bioassessment Results - Pipe Creek Watershed
October 2002

					Site					
	1	2	3	4	5	6	7	8	9	10
Chironomidae	5	5	17	4	6	1	8	19	29	1
Tipula	5	2	2	2	4	3	1	3	12	6
Stenonema	1	3								16
Stenacron					1	1		1	2	
Baetis		2						3		1
Heptagenia								1		
Isonychia								8		
Paracloedes										3
Cheumatopsyche	55	49	19	29	61			19	40	13
Hydropsyche	13	9	35	36	10	2		21	1	14
Ceratopsyche	1	7						13		16
Chimarra		1			8			1	1	9
Stenelmis	17	15	22	12	3	26	14	6	6	12
Optioservus				1		2				
Macronychus		1								
Dubiraphia			2			2				
Microcara									1	2
Berosus						12				3
Psephenus	1							1	2	2
Ischnura	1		1	1	1				1	1
Argia										1
Calopteryx				8	1	1			3	
Boyeria			1	3	3			1	1	
Sphaerium						1	1			
Corbicula	1	3								
Turbellaria			1	1	2	49	75			
Ferrissia		3					1	2		
Physella				1				1	1	
Orconectes				1						
Lirceus						1				
TOTAL	100	100	100	100	100	100	100	100	100	100

12

Pipe Creek Watershed – May 2003									
	1	2	3	4	5	6	7	8	9	10
Chironomidae	20	12	24	40	23	3	43	18	1	44
Tipula	12	2		3	3			2	3	
Simuliidae	4	1			1		2	2		4
Stenacron	8		2	14		1	2	2	3	
Stenonema		2						6	6	10
Caenis		57		3				16	4	12
Baetis								2		3
Plecoptera-Perlidae		3						1		
Cheumatopsyche	12	2	1	11	25			2	3	3
Chimarra										2
Stenelmis	28	4	14	26	36	49	44	32	38	13
Optioservus	1		3				2			
Microcara		1								
Berosus										1
Ischnura										1
Calopteryx		5								
Boyeria	16	4				4	1	2		
Sphaerium		3	34		4	12	1	6	8	1
Elimia			1							2
Turbellaria					1	1				
Ferrissia		3						6		
Physella			23		4	13	3		25	
Hirudinea			1					1	9	2
Orconectes					3					2
Oligochaeta						17	4			
TOTAL	100	100	100	100	100	100	100	100	100	100

Table 2. Data Analysis for 10/02 Samples

METRICS

	1	2	3	4	5
# of Genera	10	12	9	13	11
Biotic Index	6.5	6.1	6.8	7.1	6.4
Scrapers/Filterers	0.3	0.3	0.4	0.2	0.1
EPT/Chironomids	14	16	3.1	17	13
% Dominant Taxon	55	49	35	36	61
EPT Index	4	6	2	3	4
Community Loss Index	0.6	0.5	1.0	0.7	0.7
% Shredders	5	2	2	2	4

SCORING

	1	2	3	4	5
# of Genera	4	6	2	6	4
Biotic Index	2	2	2	0	2
Scrapers/Filterers	4	4	6	4	2
EPT/Chironomids	4	4	2	4	4
% Dominant Taxon	0	0	2	2	0
EPT Index	2	6	0	0	2
Community Loss Index	4	6	4	4	4
% Shredders	6	4	4	4	6
TOTAL	26	32	22	24	24
% of Reference	54	67	46	50	50
Impairment Category	S	S	M	M	M

N = NONE   S = SLIGHT   M = MODERATE   Sv = SEVERE

14

METRICS

	6	7	8	9	10
# of Genera	11	6	15	13	15
Biotic Index	7.2	7.5	5.8	6.5	4.6
Scrapers/Filterers	8.7	15	0.2	0.3	0.6
EPT/Chironomids	5.0	0.1	3.7	1.5	72
% Dominant Taxon	49	75	21	40	16
EPT Index	1	0	8	4	7
Community Loss Index	0.9	2.0	0.4	0.4	0.0
% Shredders	3	1	3	12	6

SCORING

	6	7	8	9	10
# of Genera	4	0	6	6	6
Biotic Index	0	0	4	2	6
Scrapers/Filterers	6	6	2	4	6
EPT/Chironomids	2	0	2	0	6
% Dominant Taxon	0	0	4	2	6
EPT Index	0	0	6	2	6
Community Loss Index	4	2	6	6	6
% Shredders	4	0	4	6	6
TOTAL	20	8	34	28	48
% of Reference	42	17	71	58	100
Impairment Category	M	Sv	S	S	N

N = NONE   S = SLIGHT   M = MODERATE   Sv = SEVERE

Summary of Aquatic Community Index Scores (Normalized to 100)

				Site Number					Watershed
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Average**
54	67	46	50	50	42	17	71	58	51

(moderate Impairment)

15

Table 3. Data Analysis for 5/03 Samples

METRICS

	1	2	3	4	5
# of Genera	8	13	9	6	9
Biotic Index	5.4	6.5	7.1	5.2	5.2
Scrapers/Filterers	2.3	1.5	1.2	3.6	1.3
EPT/Chironomids	1.2	5.3	0.1	0.7	1.1
% Dominant Taxon	28	57	34	26	36
EPT Index	2	4	2	3	1
Community Loss Index	1.3	0.5	0.9	1.7	0.9
% Mayflies	8	59	2	17	0

SCORING

	1	2	3	4	5
# of Genera	2	6	4	2	4
Biotic Index	6	4	2	6	6
Scrapers/Filterers	6	4	4	6	4
EPT/Chironomids	6	6	0	6	6
% Dominant Taxon	4	0	2	4	2
EPT Index	0	4	0	2	0
Community Loss Index	4	6	4	2	4
% Mayflies	2	6	2	4	0
TOTAL	30	36	18	32	26
% of Reference	62	75	38	67	54
Impairment Category	S	S	M	S	S

N = NONE   S = SLIGHT   M = MODERATE   Sv = SEVERE

```
                            METRICS

                      6     7     8     9    10
                     ___   ___   ___   ___   ___

# of Genera           8     9    14    10    14
Biotic Index         6.9   5.8   5.9   6.4   5.7
Scrapers/Filterers   5.3   17    4.6   6.5   3.1
EPT/Chironomids      0.3   0.1   1.6   16    0.7
% Dominant Taxon     49    44    32    38    20
EPT Index             1     1     5     4     5
Community Loss Index 1.4   1.1   0.4   0.7   0.0
% Mayflies            1     4    26    13    25


                            SCORING

                      6     7     8     9    10
                     ___   ___   ___   ___   ___

# of Genera           2     4     6     4     6
Biotic Index          2     6     6     4     6
Scrapers/Filterers    6     6     6     6     6
EPT/Chironomids       2     0     6     6     6
% Dominant Taxon      0     0     2     2     6
EPT Index             0     0     6     4     6
Community Loss Index  4     4     6     4     6
% Mayflies            2     2     6     4     6
                     ___   ___   ___   ___   ___

TOTAL                18    22    44    34    48

% of Reference       38    46    92    71   100

Impairment Category   M     M     N     S     N

N = NONE     S = SLIGHT     M = MODERATE     Sv = SEVERE
```

Summary of Aquatic Community Index Scores (Normalized to 100)

				Site Number					Watershed
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Average**
62	75	38	67	54	38	46	92	71	60 (slight Impairment)

DISCUSSION

Chemical parameters measured at each site indicate that dissolved oxygen (D.O.), pH, temperature, and conductivity fell within acceptable ranges for most forms of aquatic life. Nutrient values were relatively low and none of the sites exceeded the Indiana water quality standard for *E.coli* during October. Turbidity values at several sites (Fig. 3) were lower than the proposed turbidity criteria for the Midwest [21].

Fig. 3. Turbidity and comparison to criterion
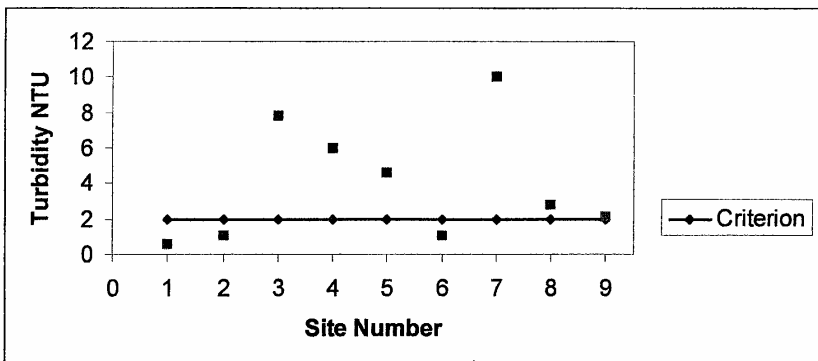
The situation in May, however, was much different. All sites exceeded the *E.coli* water quality standard for swimming and nutrient concentrations were 5 to 10 times higher than the proposed "nutrient criteria" [21] for the Midwest (Fig. 4).

Fig. 4. Nitrogen and comparison to criteria

A total of 57 macroinvertebrate genera were collected at the ten sites during October. The most commonly collected invertebrates were caddisfly larvae and riffle beetles. The pollution intolerant groups Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies) were abundant at all but two sites, but many of these were relatively tolerant net-spinning caddisflies. Truly intolerant forms were abundant at only three sites (the reference and sites 2 and 8).

Tables 2 and 4 show how the aquatic communities of the Pipe Creek watershed compared to that of the reference site. Impacted sites are shown graphically in Figure 5. Pipe Creek stream impairment ranged from "slight" at four sites to "severe" in the upper end of Honey Creek.

Figures 6 and 7 show the normal relationship of biotic index scores to habitat values (a linear relationship according to [4]). The figure also shows a range of plus or minus 10% to account for a certain amount of measurement variability. When biotic index values fall outside this range, the site typically has degraded water quality. The figures indicates that seven of the nine study sites had biotic values within the range expected from its measured habitat value. Habitat degradation is probably the primary cause of impairment at these sites.

In October, two sites (1 and 7) had biotic values much lower than their habitat values. Therefore, both habitat and water quality degradation contribute to impairment in these areas. Two additional sites (4 and 9) were identified as having water quality degradation during May.

19

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In October, two sites (1 and 7) had biotic values much lower than their habitat values. Therefore, both habitat and water quality degradation contribute to impairment in these areas. Two additional sites (4 and 9) were identified as having water quality degradation during May.

Figure 5.
Biological Impairment in the Pipe Creek Watershed
Green = None   Yellow = Slight
Blue = Moderate   Red = Severe
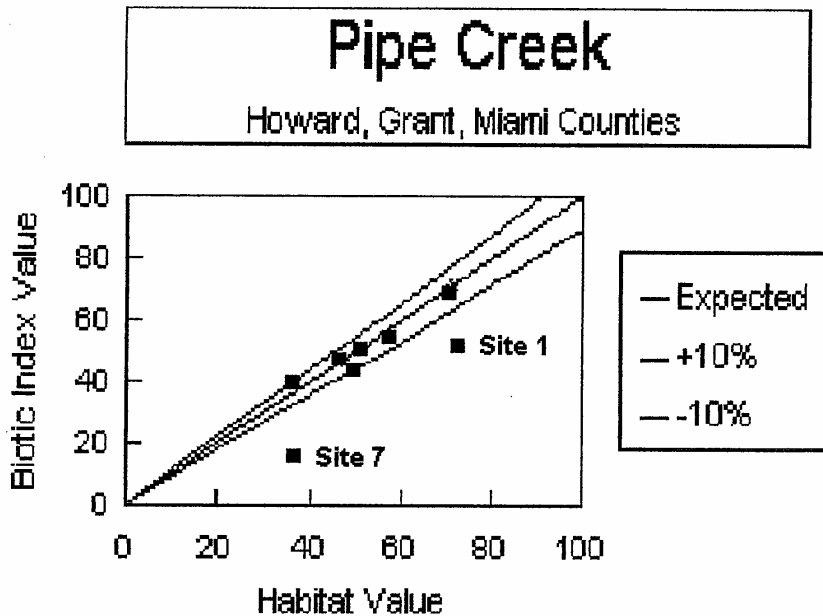
October 2002   **May 2003**

Figure 6.

The normal relationship between habitat and biotic index score is shown below. Sites falling outside the normal relationship (plus or minus 10%). are probably affected by degraded water quality.

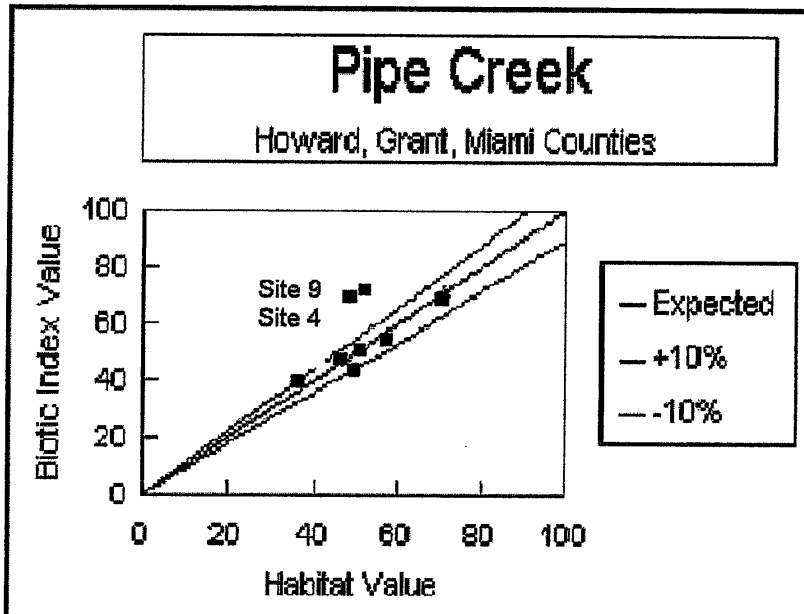**October 2002**

Pipe Creek

Howard, Grant, Miami Counties

Figure 7.

The normal relationship between habitat and biotic index score is shown below. Sites falling outside the normal relationship (plus or minus 10%). are probably affected by degraded water quality.

May 2002

Table 4 shows sediment-tolerance values for many of the commonly collected animals in these streams. The proportion of sediment and turbidity-intolerant forms was much higher at the reference site than at any of the study sites. These results indicate that sediment-related impairment may be contributing to the water quality problems in the Pipe Creek watershed. This is especially true at sites 3,4,6 and 7 the upper parts of Little Pipe Creek, Sugar Creek, and Honey Creek, where almost no sediment-intolerant forms of life were found.

Table 4. Sediment-Intolerant Species Observed
(Literature references to the species as an indicator are shown in brackets)

Stenonema vicarium	[10] [15]
Ceratopsyche spp.	[10]
Tipula spp.	[10]

% Sediment-Intolerant Organisms at the Reference	Site 10	4 7 %
% Sediment-Intolerant Organisms at the Study Sites		
	Site 1	6%
	Site 2	10%
	Site 3	2%
	Site 4	2%
	Site 5	12%
	Site 6	3%
	Site 7	1%
	Site 8	17%
	Site 9	13%

The Hilsenhoff Biotic Index (HBI), which is very sensitive to dissolved oxygen deficits, was in the "significant organic inputs" range at most sites. This means that dissolved oxygen levels probably get too low to support healthy aquatic communities, especially where the HBI exceeded 7 (sites 4, 6, and 7).

Comparison to Previous Studies

The reference stream (Little Deer Creek) was studied by Simon & Dufour [5]. They found the following fish characteristics at a site they collected in 1994:

	Observed	IBI Score
Number of species	20	5
Number of darter species	3	5
Number of sunfish species	3	3
Number of sucker species	3	3
Number of sensitive species	9	5
Percent tolerant fish	6	5
Percent omnivorous fish	1	5
Percent insectivorous fish	76	5
Percent pioneer fish	27	3
Percent lithophilic fish	19	1
Number of fish caught per hour	140	3
Percent of fish with tumors or lesions	0	5

The total IBI score of this site was 48 out of 60, which ranks it in the "good" category of biotic integrity. If it's full potential of biotic integrity is restored, Pipe Creek could be expected to support a similar fish and benthic community.

RECOMMENDATIONS

1.   To improve water quality, it may be necessary to find and fix
      sources of impairment upstream from the study area (above
      site 1). The other high priority areas for improvement are the
      upper end of Honey Creek and Little Pipe Creek.

2.   Work toward continued protection of the vegetative buffer
      zone along the stream corridors. Tree plantings along
      streams should be encouraged to improve habitat.

3.   Discourage channelization of the stream. Minimizing
      channelization allows the streams to retain a natural
      channel that enhances aquatic habitat.

4.   Discourage direct access to the streams by livestock. Large
      numbers of livestock can trample stream banks, decreasing
      the ability of streamside vegetation to filter out
      pollutants and hastening erosion.

5.   Consider a bank stabilization program on some of the headwater
      streams. Use vegetative stabilization techniques rather than
      rip-rap whenever possible.

6.   Continue to monitor Pipe Creek every 3 to 5 years
      to determine whether conditions improve. Consider conducting a
      fish community study to supplement the benthos data.

7.   Continue to encourage volunteer monitoring in the watershed.
      Such programs provide invaluable educational opportunities and
      give participants a sense of ownership in the water quality
      improvements observed over the years.

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28